LET'S MOVE NASHVILLE
Metro's Transportation Solution

Ridership Forecasting Technical Memorandum

December 8th, 2017

Forecasting Methodology

The ridership forecasts for various Systems Plan scenarios are being developed using Federal Transit Administration's (FTA) modeling software called Simplified Trips On Project Software (STOPS). The STOPS model is a stand-alone ridership forecasting software package developed by FTA. The software applies a set of travel models to predict detailed travel patterns on fixed guideway systems. STOPS was specifically developed to support FTA Capital Investment Grant Program and funding eligibility related New Starts and Small Starts funded projects.

STOPS utilizes a modified four-step (trip generation, trip distribution, mode choice, and trip assignment) model structure to quantify total transit ridership by trip type, mode of access and auto ownership. It also computes the change in person miles travelled (PMT) that is attributable to the proposed transit project. The component sub-models in STOPS have been calibrated with local adjustments and compared to rider-survey datasets from locations within six metropolitan areas (with a total of 10 lines), and validated against stop-specific counts of trips in nine other metropolitan areas (with a total of 14 lines), resulting in 24 total fixed-guideway systems.

The ridership forecasts for this study are being developed using STOPS Version 2.0.

STOPS Model Inputs

Several inputs are required to successfully complete a model run. They are listed below.

- Bus Stop/Rail Station File
- Census Data
- MPO/COG Data
- Transit Agency Data
- Additional Inputs

Bus Stop/Rail Station File

The bus stop/rail station file contains several fields needed for STOPS such as station names, daily boardings (only for calibration purposes), station types (park-and-ride, or no park-and-ride; at-grade or grade-separated), and stop IDs. This information is used to link to the General Transit Feed Specification (GTFS) data supplied by the transit agency.

Census Data
STOPS requires Journey to Work (JTW) trip flow data from U.S. Census surveys to jump start the modeling process. JTW data provides actual distribution of total trips (all modes combined) and transit trips in the study area. The STOPS model uses this distribution and observed transit mode shares to calibrate the model. For this study, the year 2010 JTW trips flows were available directly from FTA, and therefore, used in the development of the model.

MPO/COG Data
Demographic data and peak highway travel times from the local Metropolitan Planning Organization or Council of Governments are needed as inputs to STOPS. Total population, total employment, and AM peak highway travel times for the Existing, No Build, and Build scenarios were acquired from the Nashville Area MPO regional travel model for years 2015 and 2040. The ridership analysis was conducted for year 2015 and 2040. The 2015 Model is called the Existing Conditions model. It is based on 2015 transit network and demographic and land use data. The 2040 Model represents the long term conditions.

Transit Agency Data
GTFS is a standardized format for public transportation schedules used by transit agencies throughout the world. GTFS is a collection of text files that together provide schedule and stop data necessary for trip planners, schedules, and mobile phone applications. STOPS utilizes GTFS for estimating ridership in the Existing, No Build, and Build scenarios. GTFS files for were acquired from the Nashville Metropolitan Transit Authority/Regional Transportation Authority of Middle Tennessee and used as input data that feeds the STOPS model.

Additional Inputs/Modifications
There are several inputs that are optional in STOPS. These include the following:

- Weekday Unlinked Transit Trips
- Weekday Home-Based Work (HBW) Linked Transit Trips
- Ratio of Home-Based Other (HBO) to HBW trips by Auto Occupancy
- Ratio of Non-Home-Based NHB to HBW trips by Auto Occupancy

For this transit program, the first optional input was used as supplied by the transit agency. For the last three optional inputs default values embedded in the STOPS model were used.

STOPS Service Scenarios
There are three service scenarios required by STOPS: Existing Transit, No Build, and Build. This section will explain each of the scenarios and inputs used for this project.

Existing Transit Scenario
The existing transit scenario is a critical element of the ridership estimation process because it builds the foundation for all future model runs. The input data used to create the Existing Scenario corresponds to year 2015 and the 2015 GTFS was used.

No-Build Scenario

The No Build scenario was assumed to be identical to the Existing Scenario except current (2017) transit GTFS was used.

Build Scenario: Scenario 1E

The Build Scenario contains three new interlined Light Rail Transit (LRT) lines developed as part of the transit program (**Scenario 1E).** The interlined lines are as follows:

- Gallatin Pike LRT (Briley) to Nolensville Pike LRT (Harding Place)
- Charlotte Avenue LRT (White Bridge Road) to Murfreesboro LRT (Airport)
- NW Corridor LRT (Buchanan to SoBro Transit Center)

Figure 1 shows an abstract representation of the high capacity transit network coded in the model. The initial interlining concepts were simplified for the initial modeling runs. As corridor development activities occur, the interlining pairs and the actual service plan will be refined. Please note the operating assumptions were made strictly for ridership forecasting and operating cost estimating purposes. It is based on 10 minute peak headways in each of the five corridors. The actual operating plan will be developed and optimized during planning, project development and design.

The average operating speeds between stations was assumed to be about 18 MPH and in the tunnel section, about 17 MPH. The hours of operation and headways are shown in **Table 1.**

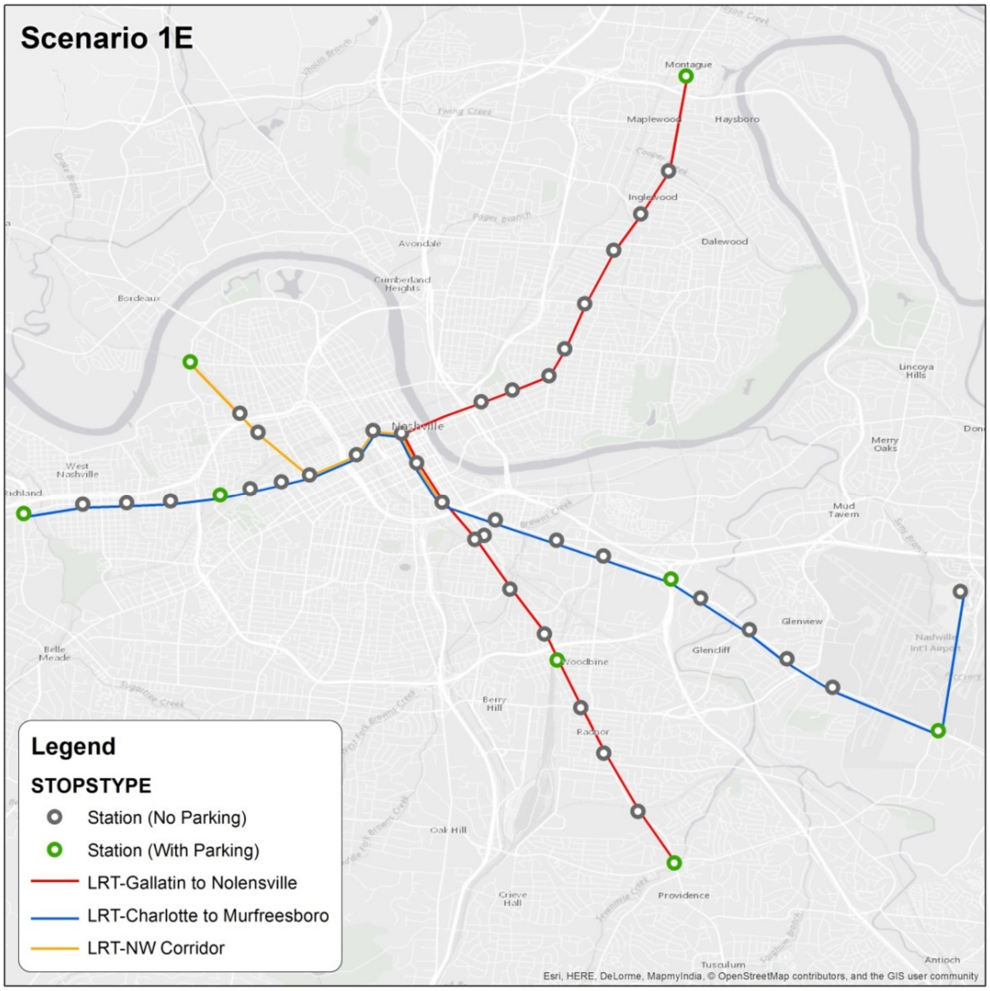
Table 1: DRAFT Operating Assumptions

Time Periods	Headways
5:00 AM to 6:00 AM 6:00 AM to 6:00 PM 6:00 PM to 1:00 AM	20 (Off-peak) 10 (Peak) 20 (late night)

Source: HDR Engineering

Conceptual station locations and configurations were generalized for establishing ridership forecasts and program capital and operational costs. Inputs for this high level planning effort included the nMotion Plan recommendations and industry practices regarding average station spacing. More precise station locations will be determined through detailed planning, design, environmental analysis, and community and stakeholder involvement activities during project development of each corridor.

Figure 1: Transit Lines Coded in Scenario 1E



Source: HDR Engineering

Ridership Forecasts

Ridership forecasts for different travel markets were estimated using multiple methodologies as described in the following sections. The STOPS model was used to forecast the LRT ridership for work and non-work related trip purposes. An elasticity-based sketch planning methodology was used to quantify the ridership impact of service improvements on selected bus routes that the Nashville Metropolitan Transit Authority (MTA) is planning to implement. To capture airport related trips more accurately, Peer City transit mode shares were used along with the travel forecasts estimated by Nashville MPO's regional travel demand model. A brief description of the elasticity-based approach and Peer City Mode Share approach is provided later in this memorandum.

As summarized in **Table 2**, our analysis shows by 2040, the total system wide ridership in the entire Nashville metro area is likely to reach anywhere between 114,500 and 131,000 boardings per day if all the planned improvements including the construction of the LRT lines are implemented.

Table 2: Summary of Ridership Forecasts

(Average daily weekday and annual boardings)

	2040 Build Ridership (Weekday)	2040 Build Ridership (Annual)
Projected ridership resulting from 30 percent service improvements on selected 14 Local Bus Routes and 5 Rapid bus routes and modest improvements on remaining local and express routes	53,500 to 60,000	16.3 mill to 18.3 mill
LRT (3 interlined LRT Lines)	61,000 to 71,000	18.6 mill to 21.7 mill
Total System Ridership	**114,500 to 131,000**	**34.9 mill to 39.9 mill**

Source: HDR Engineering

STOPS Model Ridership Results

The STOPS model outputs a variety of results, including a summary of linked/unlinked[1] trips, the change in person miles traveled (PMT), system-wide ridership by mode, daily rail ridership, trips on project by trip purpose, and daily station boardings and alightings on the LRT service. The model was run for 2015 and 2040. The forecast results discussed in this memorandum are for those two years.

In ridership modeling, regardless of the type of model used, there are always some uncertainties associated with forecasts. These uncertainties can be categorized into three groups:

- Uncertainties associated with major input assumptions such as forecasts of population, employment and socio-economic variables and representation of highway and transit levels of service.
- Uncertainties associated with project's service and operations plan. For example, it is possible the transit operating agency may offer the exact service levels assumed in the model for a multitude of reasons such as adjustments to the actual demand. Also, it is possible the underlying transit network in the long term forecast year may not be exactly the same as the one assumed in the travel model. These service and network changes may produce somewhat different ridership than what was estimated in the model.
- Uncertainties associated with limitations of travel models in general. Travel modeling is not an exact science since it involves simulating human behavior (as it relates to how travel decisions are made). The transportation modeling industry has made significant advances in the past several decades in improving the simulation and forecasting of travel demand; but still there is

[1] A linked passenger trip includes segments of travel from point-of-origin to point-of-final-destination as a single trip, regardless of transfers or intermediate stops. An unlinked transit trip, on the other hand is the same as a passenger boarding. An unlinked trip is counted each time a passenger boards a transit vehicle, regardless of bus transfers, transfers from a personal automobile, or whether he or she walked to a transit station. Counting unlinked trips gives a discrete accounting of the actual potential usage of the build alternatives. It is important to note that individual will likely have more than one transit trip per day—at least one on the way to work and one on the way home. Each trip is counted separately in this analysis. Throughout this section, the terms boardings, riders, and trips all refer to unlinked passenger trips.

always a chance for some inherent errors associated with model specification, data collection, sampling and data aggregation.

In order to make allowance for the above factors, industry leaders recommend that the ridership forecasts be presented in a range as opposed to a single number. In this memorandum, ridership numbers are presented in ranges to account for the uncertainties in forecasting.

The raw model results shown in **Table 3** indicate the LRT projects in this transit program are likely to increase the total system wide linked transit trips from approximately 39,207 in the No Build alternative to 81,804 in the Build alternative resulting in an increase of about 42,600 trips in 2040. However, in reality, the increase in linked transit trips is most likely to be between 38,400 and 44,800 as shown in **Table 3**. Most of this increase represents new transit trips, meaning, they are the result of trip diversion from auto mode to transit mode. In other words, this transit program has the potential to divert anywhere from 38,400 to 44,800 auto person trips from the highway system to the transit system on a typical weekday in the forecast year 2040. This level of diversion would most likely result in a reduction of anywhere from 190,000 to 210,000 vehicle miles travelled (VMT) on the highway system.

As shown in **Table 3,** the total daily ridership on all of the three interlined lines is estimated to be anywhere from 61,000 to 71,000 boardings a day in 2040.

Table 3: Ridership Forecast Summary

(Average weekday daily boardings)

Model Statistics	2015 Raw Results	2015 Likely Range	2040 Raw Results	2040 Likely Range
No Build Scenario -Linked transit trips in the entire system (all bus routes)	27,117	25,000 to 28,000	39,207	35,500 to 41,000
No Build Scenario -Unlinked transit trips in the entire system (all bus routes)	38,117	34,500 to 40,000	56,230	51,000 to 59,000
Build Scenario -Linked transit trips in the entire system (bus and LRT routes)	45,902	41,400 – 48,200	81,804	73,700 – 85,900
Build Scenario -Unlinked transit trips in the entire system (bus and LRT routes)	63,668	57,400 – 66,900	114,877	103,400 – 120,700
Increase in Linked transit trips (auto Diversion)	18,785	17,000 – 19,800	42,597	38,400 -44,800
Increase in Unlinked transit trips	25,551	23,000 – 26,900	58,647	52,800 – 61,600
Total Line Boardings (Ridership)				
Gallatin to Nolensville-LRT	14,777	13,300 – 15,600	26,455	23,900 – 27,800
Charlotte to Murfreesboro- LRT	14,077	12,700 – 14,800	29,577	26,700 – 31,100
NW Corridor to So.Bro TC - LRT	5,137	4,700 – 5,400	9,200	8,300 – 9,700
Model Based Total Line Boardings (Ridership)	**33,991**	**30,600 – 35,700**	**65,232**	**58,800 – 68,800**
Off-Model Ridership	N/A		2,395[a]	
Total Line Ridership	**33,991**	**30,600 – 35,700**	**67,627**	**61,000 – 71,000**

Source: HDR Engineering

[a] – see sections Airport Ridership and Ridership Impact of Service Improvement on Buses for source of off-model ridership.

The daily boardings at the station level are shown in **Table 4**. As seen, Music City Central, 5th Ave and Broadway, SoBro Transit Center, Gallatin Pike and Walton Lane, Rosa Parks Blvd/James Robertson, Charlotte Avenue and 28th Avenue, Charlotte Avenue at 11th Avenue, Nolensville and Harding Place, Nolensville and Antioch Pike, Nolensville and Peachtree Street, BNA Terminal, Murfreesboro Pike and Donelson Pike, Murfreesboro Pike and I-24 are among the stations with very high ridership activity. All of the park-and-ride stations with the exception of Ed Temple station, Charlotte Ave /White Bridge Road and Nolensville/Peachtree station would have a demand of more than 1,000 daily Park and Ride boardings.

Table 4: Daily Ridership by Station (Year 2040)

Station Name	Walk Access	Kiss & Ride Access	Park & Ride Access	Transfers	Total Boardings[a]	Likely Range Low	–	High
Music City Central	3,479	68	0	9,021	**12,568**	12,000	–	13,200
5th Ave and Broadway	5,586	15	0	1,670	**7,271**	7,000	–	7,700
SoBro Transit Center	4,044	80	0	2,569	**6,693**	6,400	–	7,100
Gallatin Pike and Walton Ln	430	534	1,096	7	**2,067**	2,000	–	2,200
Gallatin Pike and Curdwood/Ardee	286	47	0	58	**391**	400	–	500
Gallatin Pike and Greenfield Ave	337	16	0	56	**409**	400	–	500
Gallatin Pike and Trinity Lane	419	50	0	12	**481**	500	–	600
Gallatin Pike and Douglas Ave	375	13	0	0	**388**	400	–	500
Gallatin Pike and Eastland Ave	490	6	0	69	**565**	600	–	600
Main St and 10th St	339	8	0	42	**389**	400	–	500
Main St and 8th St	408	1	0	34	**443**	500	–	500
Main St and 5th St	956	1	0	53	**1,010**	1,000	–	1,100
Rosa Parks Blvd and James Robertson	1,911	13	0	400	**2,324**	2,300	–	2,500
Charlotte Ave and White Bridge Rd	466	308	449	48	**1,271**	1,300	–	1,400
Charlotte Ave and 49th Ave	355	18	0	30	**403**	400	–	500
Charlotte Ave and 42nd Ave	542	8	0	0	**550**	600	–	600
Charlotte Ave and 37th Ave	647	6	0	2	**655**	700	–	700
Charlotte Ave and 28th Ave	458	179	1,113	161	**1,911**	1,900	–	2,100
Charlotte Ave and 25th Ave	562	0	0	1	**563**	600	–	600
Charlotte Ave and 21st Ave	922	0	0	27	**949**	1,000	–	1,000
Charlotte Ave and 18th Ave	1,218	15	0	391	**1,624**	1,600	–	1,800
Charlotte Ave and 11th Ave	1,329	2	0	766	**2,097**	2,000	–	2,300
Ed Temple Station	527	237	437	0	**1,201**	1,200	–	1,300
Heiman Station	309	7	0	20	**336**	400	–	400
Alameda Station	678	2	0	46	**726**	700	–	800
Nolensville Pike and Harding Place	1,107	1,125	2,275	311	**4,818**	4,600	–	5,100

Station Name	Walk Access	Kiss & Ride Access	Park & Ride Access	Transfers	Total Boardings[a]	Likely Range Low		High
Nolensville Pike and Zoo Rd	729	12	0	0	**741**	800	–	800
Nolensville Pike and Antioch Pike	1,081	11	0	0	**1,092**	1,100	–	1,200
Nolensville Pike and Thompson Ln	244	9	0	56	**309**	300	–	400
Nolensville Pike and Peachtree St	363	120	730	0	**1,213**	1,200	–	1,300
Nolensville Pike and Glenrose Ave	270	1	0	0	**271**	300	–	300
Nolensville Pike and Walsh Rd	261	1	0	24	**286**	300	–	400
2nd Ave and Chestnut St	188	0	0	204	**392**	400	–	500
4th Ave and Chestnut St	213	3	0	27	**243**	300	–	300
BNA Terminal	1,283	23	0	14	**1,320**	1,300	–	1,400
Murfreesboro Pike and Donelson Pike	1,140	942	2,329	120	**4,531**	4,400	–	4,800
Murfreesboro Pike and Pineway Dr	456	13	0	84	**553**	600	–	600
Murfreesboro Pike and Glengarry Dr	519	12	0	42	**573**	600	–	700
Murfreesboro Pike and Thompson Ln	169	9	0	131	**309**	300	–	400
Murfreesboro Pike and Pavilion Blvd	691	12	0	0	**703**	700	–	800
Murfreesboro Pike and I-24 BRT	220	307	1,254	23	**1,804**	1,800	–	1,900
Murfreesboro Pike and Foster Ave	275	0	0	63	**338**	400	–	400
Murfreesboro Pike and Elm Hill Pike	270	2	0	1	**273**	300	–	300
Lafayette St and Charles Davis Blvd	408	4	0	161	**573**	600	–	700
TOTAL	**36,960**	**4,240**	**9,683**	**16,744**	**67,627**	**61,000**	–	**71,000**

Source: HDR Engineering

[a] – Red denotes high ridership station with daily boardings greater than 2,000

Table 5 shows the LRT ridership for downtown stations as well as for each of the five corridors. Passenger boardings at stations that are shared by two corridors were split equally and allocated to each corridor. Annual boardings which were calculated using an annualization factor of 305 are also shown in the table.

Table 5: Ridership Forecast Summary

	Weekday Boardings	Likely Range Low - High	Annual Boardings Low		High
Downtown stations	26,532	23,900 - 27,900	7,289,500	-	8,509,500
Gallatin Corridor	6,143	5,600 - 6,500	1,708,000	-	1,982,500
Charlotte Ave Corridor	9,731	8,800 - 10,300	2,684,000	-	3,141,500
NW Corridor	4,880	4,400 - 5,200	1,342,000	-	1,586,000
Nolensville Corridor	9,652	8,700 - 10,200	2,653,500	-	3,111,000
Murfreesboro Corridor	10,691	9,700 - 11,300	2,958,500	-	3,446,500
Total	**67,627**	**60,900 - 71,100**	**18,574,500**	-	**21,685,500**

Source: HDR Engineering

Airport Ridership

The STOPS model is not designed to capture all travel markets associated with airport trips. Since it uses Census-based work trips as a starting point, it captures the employee based airport trips reasonably well. However, an important component of airport demand that is not captured by the STOPS model properly, involves trips attracted to the Nashville area for other trip purposes. This component was quantified in this study using a simplified off-model procedure. This procedure involved researching transit ridership patterns at major US airports that have rail access to the airport, correlating their transit demand to their annual enplanements and applying transit splits of selected peer cities to Nashville area and estimating transit trips that use rail as access and egress mode.

The research data used in this off-model procedure are summarized in a report published by Airport Cooperative Research Program (ACRP Report 4) entitled **Ground Access to Major Airports by Public Transportation**. The report provides market share by public transit modes for 21 major US airports and their corresponding annual airport traffic (enplanements). According to the Metropolitan Nashville Airport Authority's (MNAA) comprehensive long range plan, called the BNA Vision, the Nashville area's population is expected to exceed 2.5 million by 2035. The international airport traffic is projected to increase from 12 million enplanements today to 20 million by 2035. As shown in **Table 6**, the data published in the ACRP's report indicates the transit mode share at US airports that have good rail access and that process volumes in the range of 14 to 20 million enplanements vary between 6 and 17 percent. For the Nashville airport (BNA), a transit mode share of 9 percent was assumed. Using the Nashville MPO regional model, the total number of trips originating from and destined to the zone containing the BNA airport was summarized for all trip purposes. For the year 2040, the MPO model indicated there would be about 21,650 trips associated with the airport using all transportation modes. Applying a mode share of 9 percent, approximately 2,000 trips are estimated to board and alight at the airport station. Assuming symmetry, about 1,000 additional boardings can be expected at the airport station in 2040.

Table 6: Transit Shares of Selected US Airports

Airport	Transit Share	Annual airport traffic (million Enplanements)
Reagan National	17%	17.8
Oakland	15%	14.4
Baltimore	12%	20.1
Chicago Midway	9%	17.6
Washington/Dulles	8%	26.8
St.Louis	6%	14.7

Source: ACRP Report 4, Published in 2008

Ridership Impact of Service Improvement on Buses

Currently, the MTA is exploring several investment plans to improve the existing bus service throughout their entire transit system. The service improvement may be implemented in phases. One such plan calls for improving bus frequencies throughout the day on 18 selected bus routes. Many of these 18 routes provide intermodal connectivity to several LRT stations considered in ridership modeling. Since improving bus access to LRT stations will have a positive impact on LRT ridership, a special simplified procedure was developed to quantify the increase in LRT ridership resulting from the improved bus service. The procedure involved applying Transit Service Elasticities to capture the ridership impact of bus service improvements.

Definition of Transit Service Elasticity

In economics, price sensitivity to demand is measured using elasticities, defined as the percentage change in consumption resulting from a 1 percent change in price, all else held constant. The same concept is applied to measure transportation demand. For example, if the elasticity of transit ridership with respect to bus frequencies is 0.45, this means that each 1.0 percent improvement in bus frequency will most likely cause a 0.45 percent increase in ridership, so a 10 percent improvement in bus frequency will cause ridership to increase by about 4.5 percent. The converse is also true, i.e., a 10 percent reduction in bus frequency can cause a 4.5 percent reduction in ridership.

Application of Transit Service Elasticity to Estimate Ridership

For this study, a service elasticity of 0.50 (industry standard) was used to measure the ridership impact of adding more buses on several selected bus routes. Our procedure involved computing the total number of daily bus trips provided on each of the 18 routes based on current bus headways as well as planned headways in 2040, estimating the increase in daily bus trips by route and applying the Transit Service Elasticity to determine the ridership increase at the route level. The elasticities were also applied to the number of trips transferring from different bus routes to the LRT system at each station. The additional bus transfer trips were manually added to the LRT ridership at relevant stations**. Table 7** presents the system level ridership by transit sub-mode. As seen, the total transit ridership at the systems level is projected to increase from 35,600 today to anywhere between 114,500 and 131,000 in 2040. The LRT system ridership would make up 53 percent of the 2040 ridership.

Table 7: Systems Level Ridership Summary

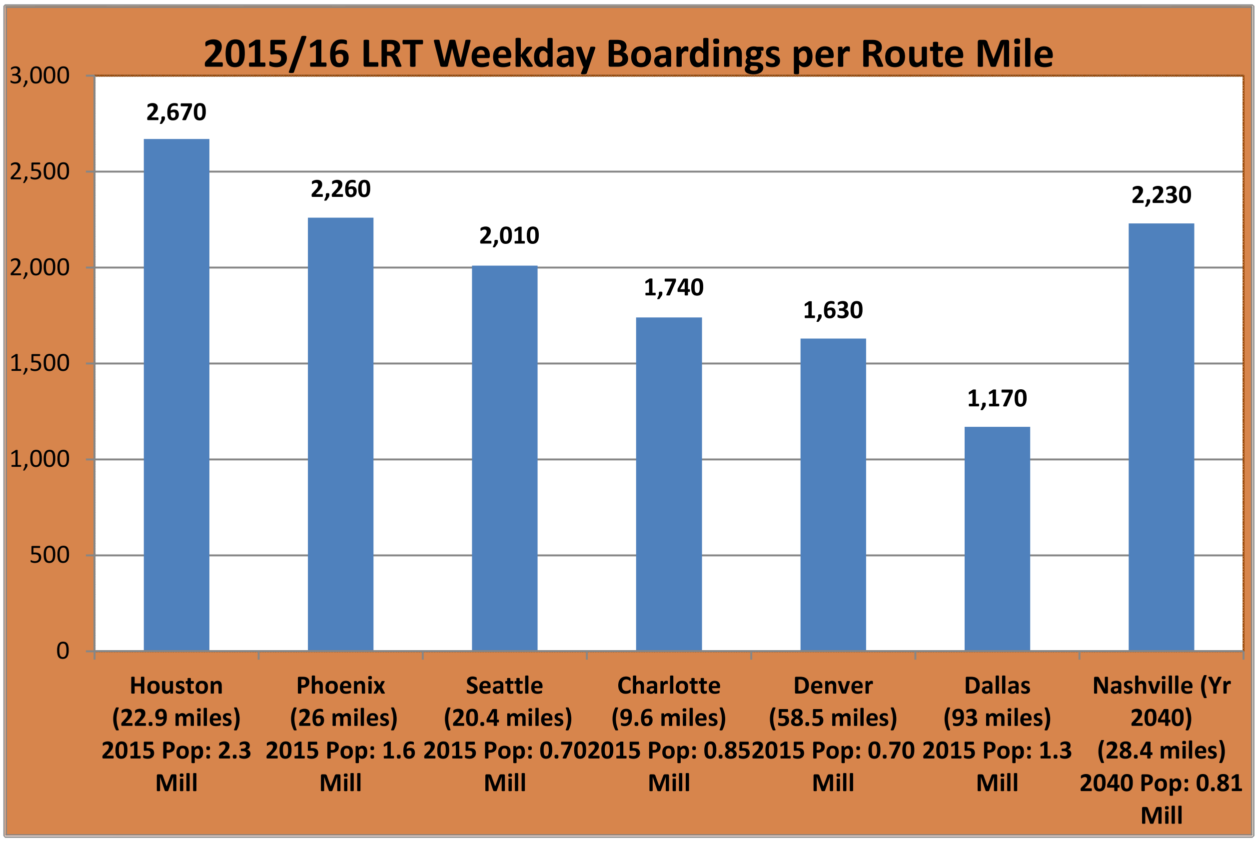
	2015 Ridership	2040 Build Ridership (weekday)	2040 Build Ridership (annual)
14 Local Bus Routes that will experience about 30 percent service improvements and the remaining local routes that will experience modest service improvements in 2040	26,650	36,500 to 41,000	11.1 mill to 12.5 mill
4 Rapid Bus Routes that will experience about 30 percent service improvements in 2040	6,400	12,500 to 13,500	3.8 mill to 4.1 mill
Express Bus	2,550	4,500 to 5,500	1.4 mill to 1.7 mill
LRT(3 interlined LRT Lines)	Not Applicable	61,000 to 71,000	18.6 mill to 21.7 mill
Total System Ridership	**35,600**	**114,500 to 131,000**	**34.9 mill to 39.9 mill**

Source: HDR Engineering

Comparison of Nashville Ridership Forecasts with Other Peer Cities

Figure 2 compares the 2015 average daily boardings on LRT systems from peer cities to the forecasted ridership on Nashville's proposed LRT system. As seen, Nashville's LRT performance in the forecast year is comparable to some of the large cities shown in the table.

Figure 2: Peer Cities Ridership Comparison



Source: National Transit Database and HDR Engineering for Nashville.
2040 Population forecasts are from Nashville Area Metropolitan Planning Organization